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# Los Alamos Seismology and Seismic Retrofit of Mission Critical Facilities

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**28 January, 2021**



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# Presentation Major Points -

- **Discussion on the seismic hazard in Los Alamos, New Mexico**

  ***- Inputs From Geology and Seismology***

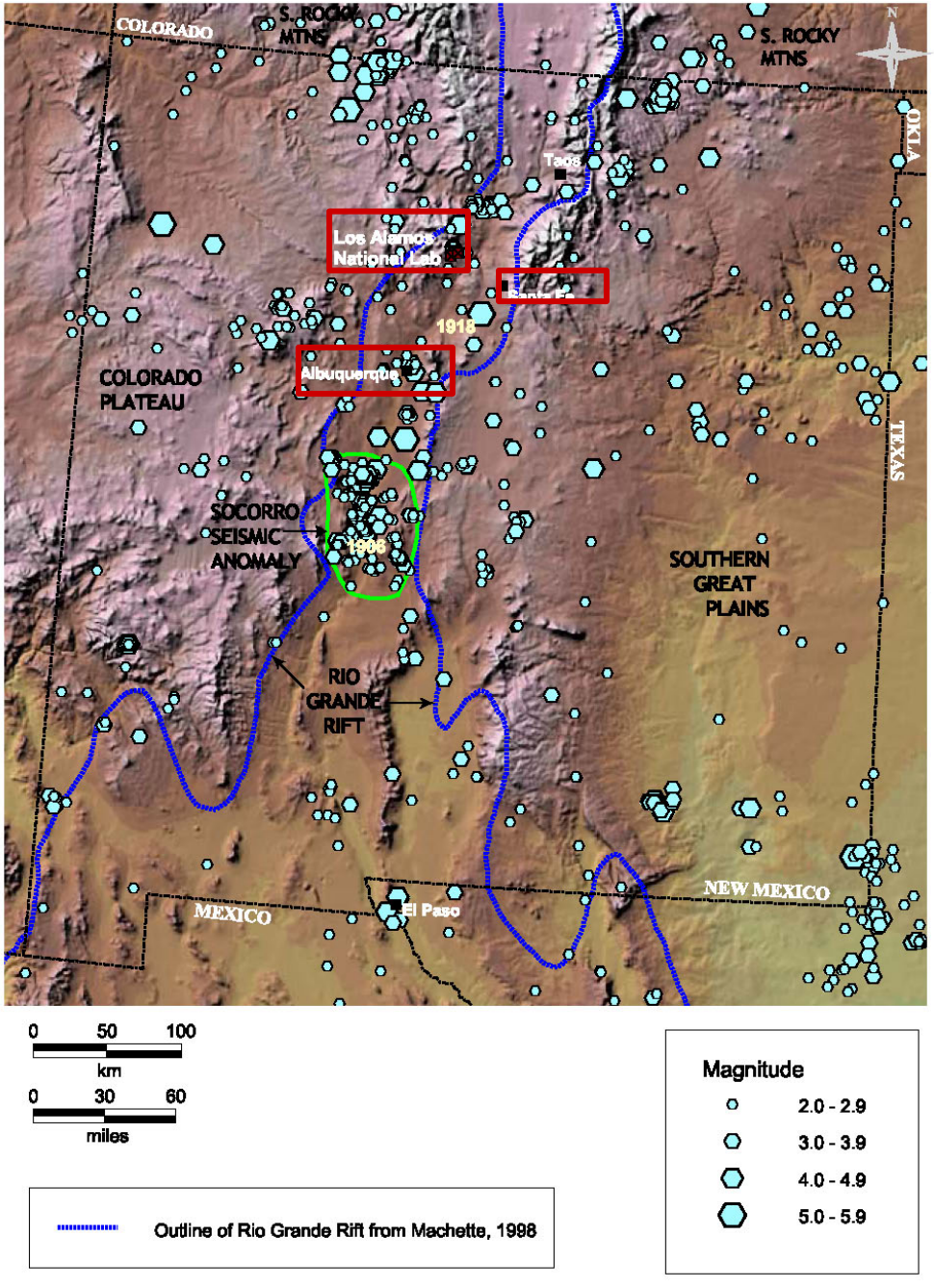
- **Ongoing Seismic Retrofit of Los Alamos National Laboratory (LANL) Plutonium Research Facility.**

  ***- Column Capital Test Program (at University of Nevada - Reno)***

# Seismicity in New Mexico

N

## Historical Seismicity, 1869 to 2005

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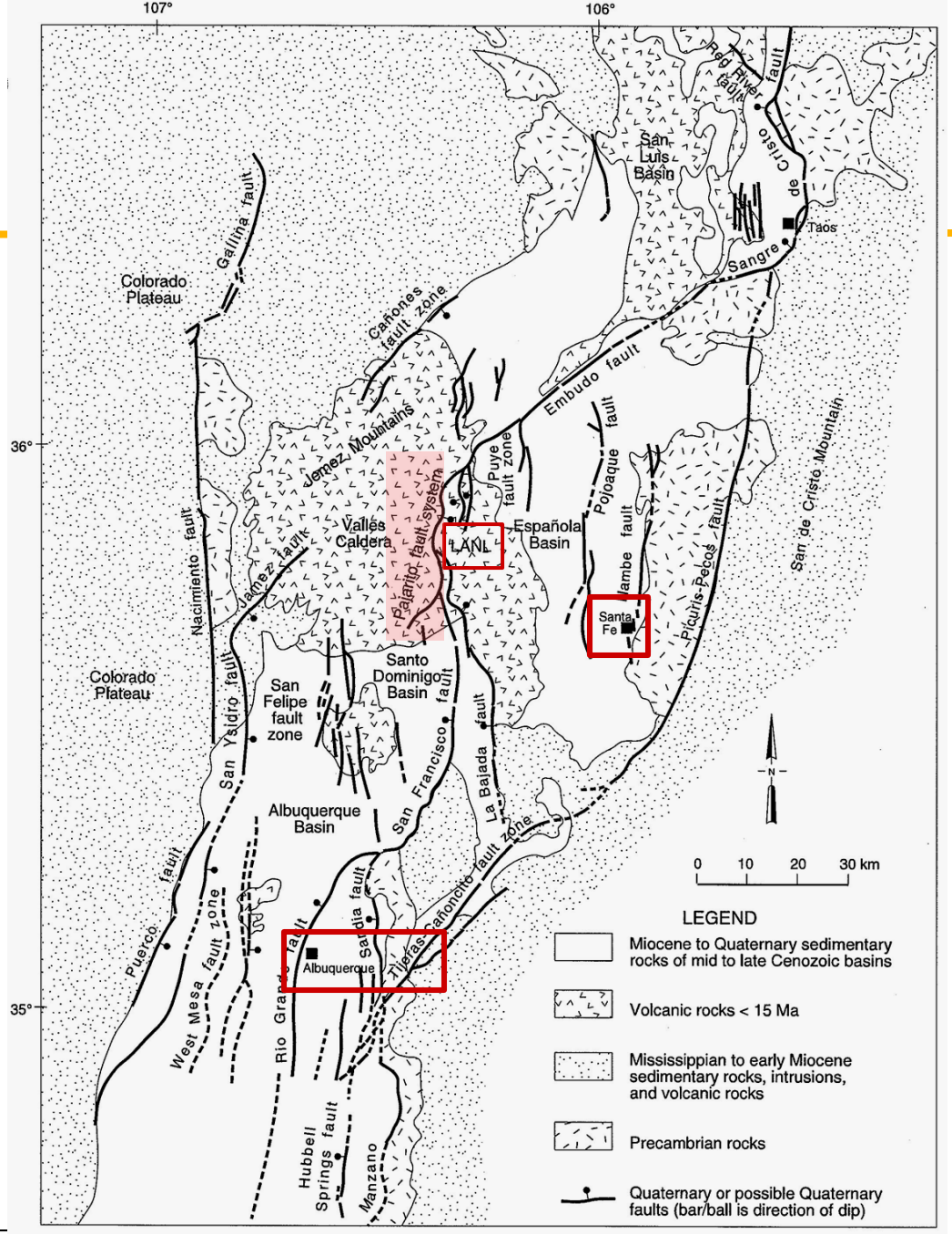
# Faulting Map of the Los Alamos Region

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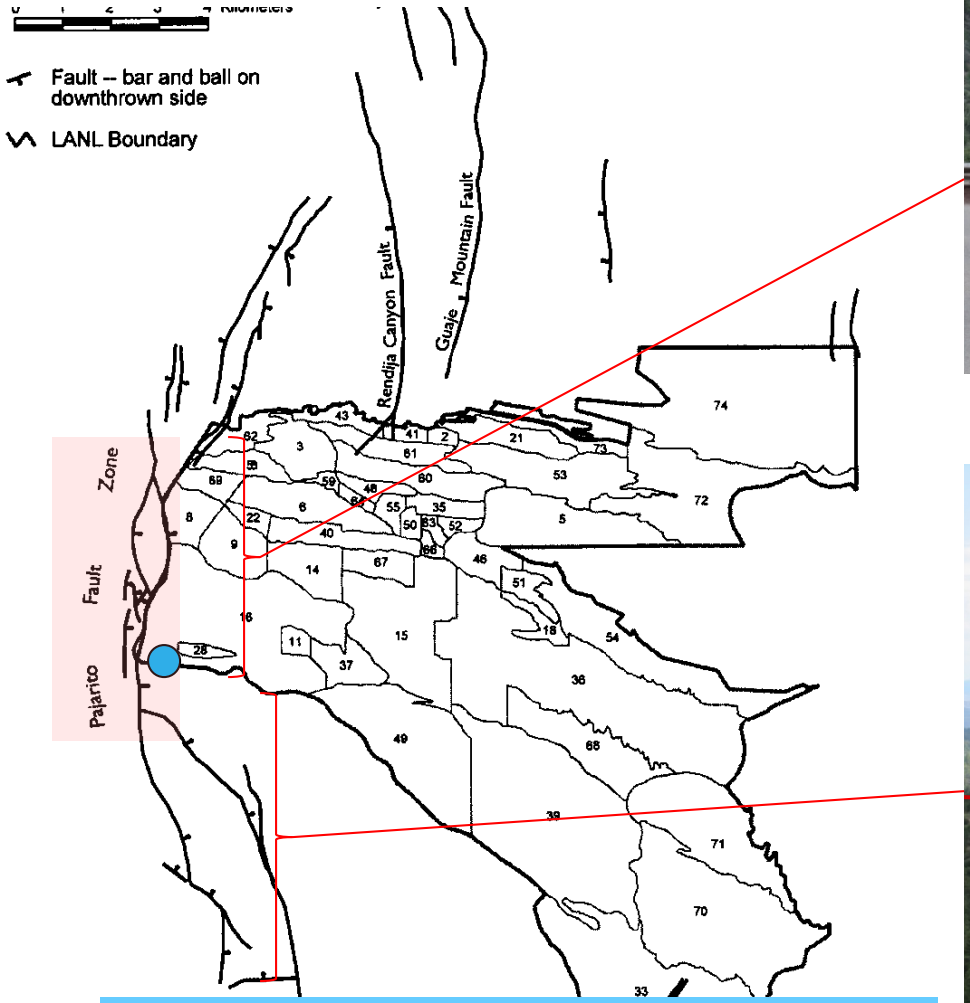
# Aerial View of LANL and Jemez Mountains

Looking West

# Faults at LANL



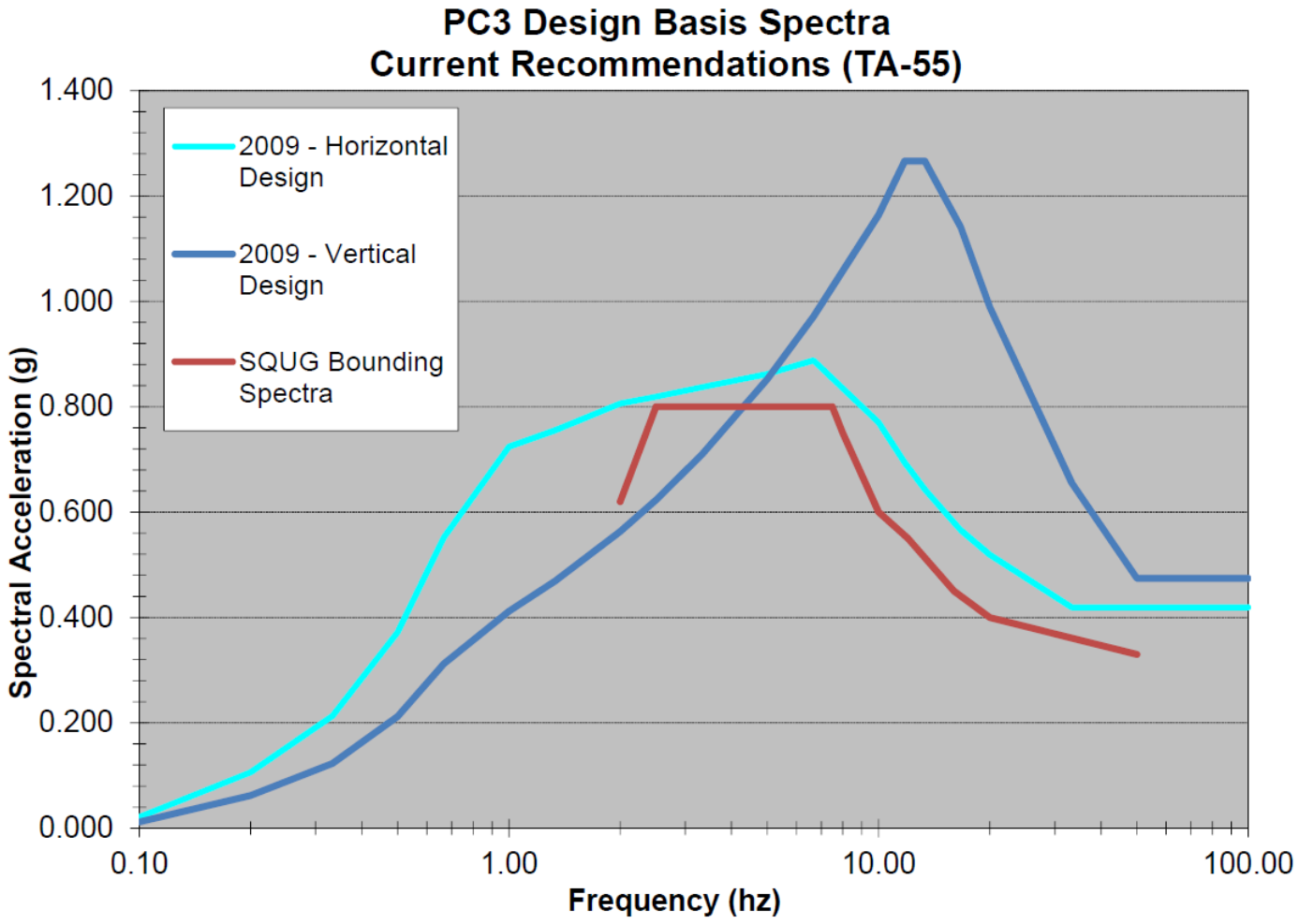

**Active Faulting in the Los Alamos Area**

Looking North

Looking South

# Fault Investigation

# TA-55 Free Field Response Spectra

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# Column Capital Test Program

# (CCTP)

# Column Capital Test Program (CCTP)

- Full-scale testing effort being carried out at University of Nevada – Reno to assess capacity of unreinforced column capitals.
- Goal to understand the fragility of the unreinforced capitals under pseudo-static loading representative of LANL seismic hazard.

# LANL Plutonium Research Facility (PF-4)

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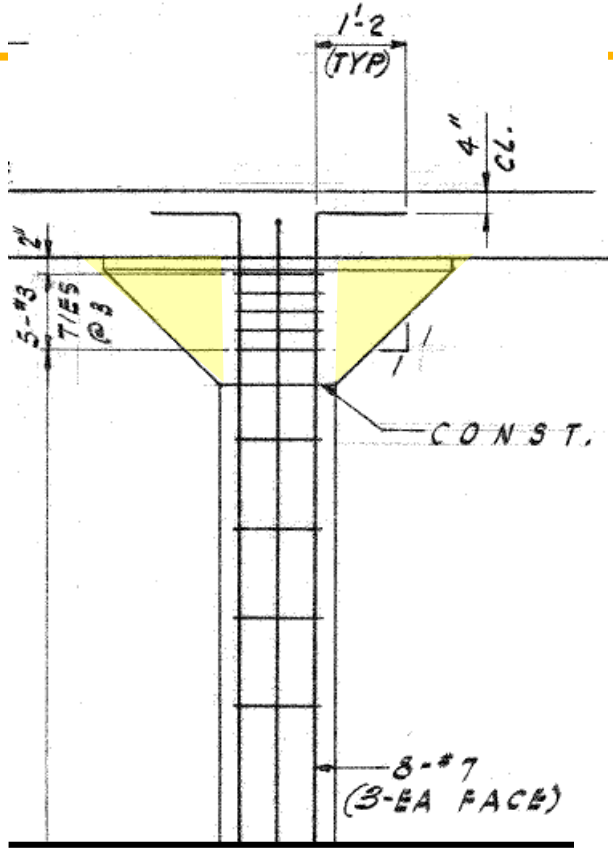
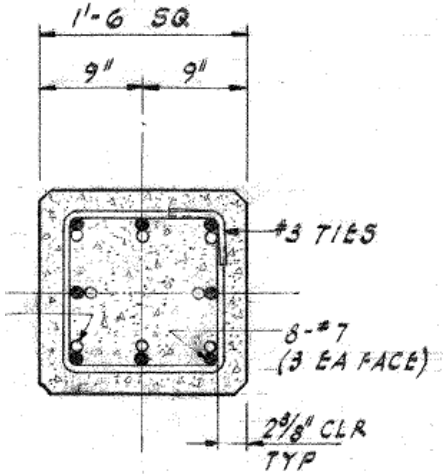
# ‘Captured’ Column in PF-4




Concern is loss of unreinforced capital leading to reduced punching shear capacity.

# Seismic Retrofit of 'Captured' Columns

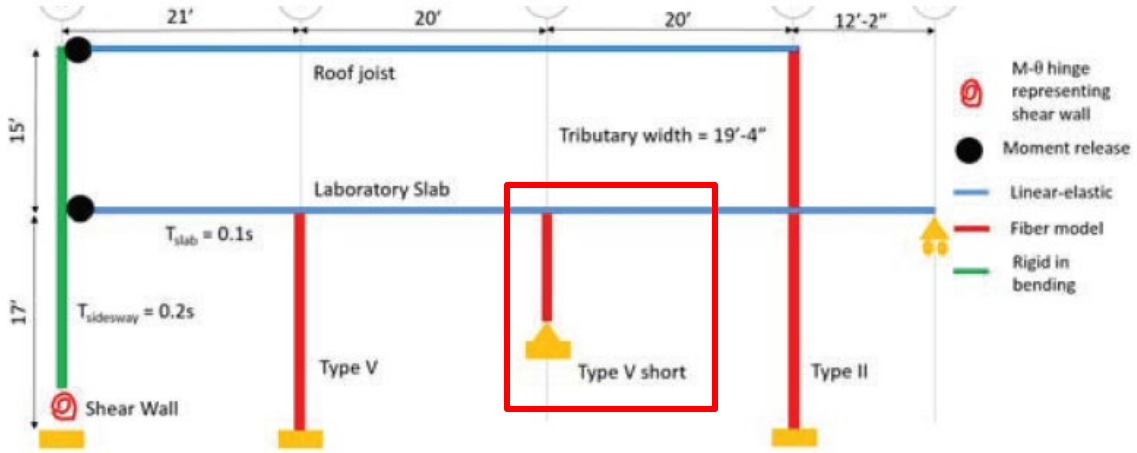
Column jacketed with 13 layers of BASF Carbon Fiber Reinforced Polymer (CFRP).

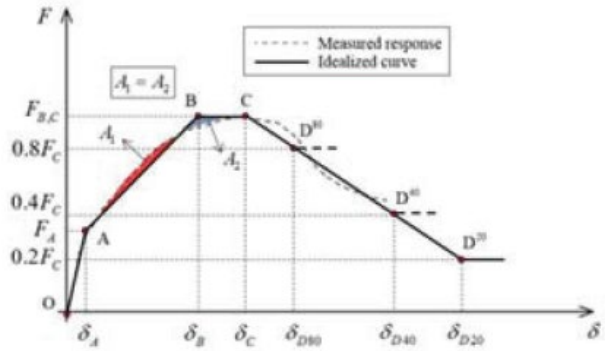
CFRP jacketing will prevent shear failure due to ties that terminate in 90-degree hooks.

CFRP jacketing will increase concrete strain $\varepsilon_c$ at failure from 0.003 to 0.01 to increase drift capacity under seismic event.

# Column Capital Test Program (CCTP)
# Defining the Loading Protocol

## Develop 2D model representing major components in building to define Axial (P) – Moment (M) phasing on Captured Columns





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# Column Capital Test Program (CCTP) Defining the Loading Protocol

## Results from modeling effort to define P-M interaction and loading on Captured Column

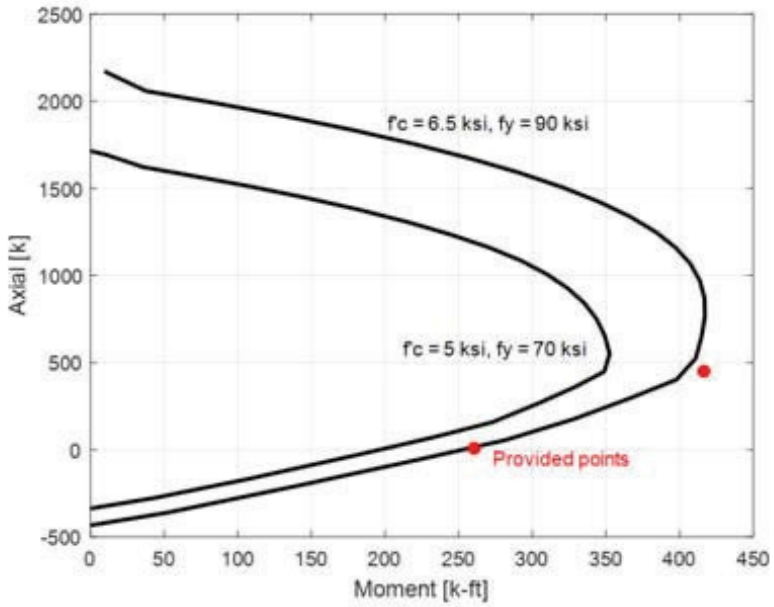



Figure 37. Moment-axial interaction diagram for Type V short column (with fiber-wrap).

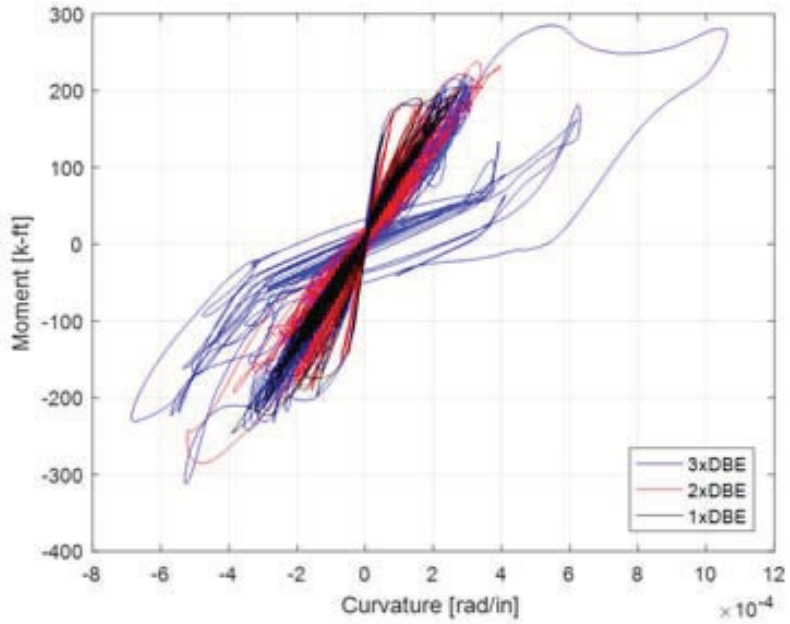



Figure 38. Sample moment-curvature response for a Type V short column subjected to different intensities of the same ground motion.

# Column Capital Test Program (CCTP) Defining the Loading Protocol

## Recommendations on Loading Protocol:

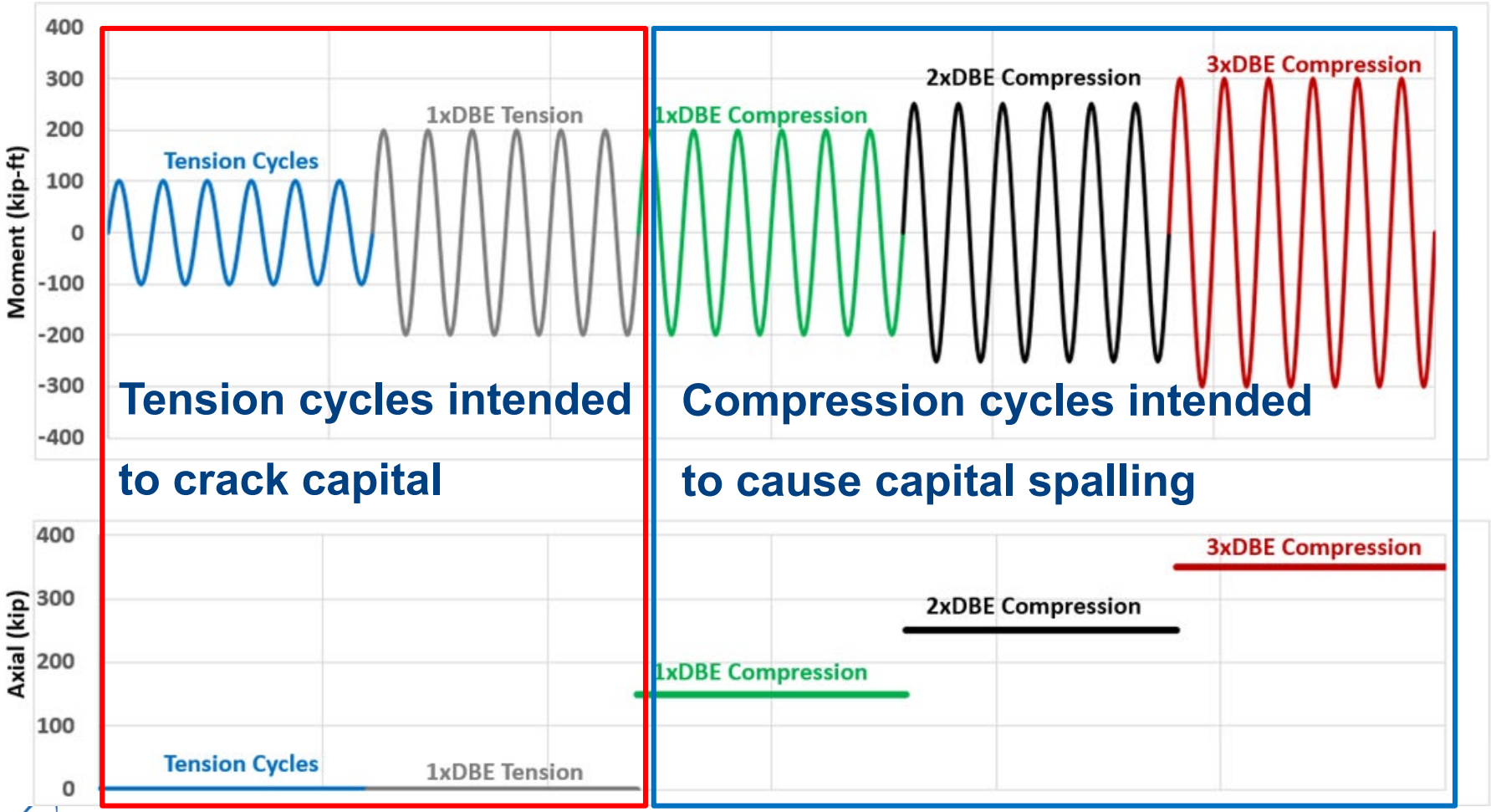
Rounded/Adjusted Envelope Type V Protocol

| | median | | | | 90%ile | | | |
|---|---|---|---|---|---|---|---|---|
| | $M^-$ | $P^-$ | $M^+$ | $P^+$ | $M^-$ | $P^-$ | $M^+$ | $P^+$ |
| 1×DBE | 200 | 100 | 200 | 200 | 225 | 65 | 223 | 160 |
| 2×DBE | 225 | 75 | 230 | 230 | 250 | 30 | 260 | 250 |
| 3×DBE | 250 | 50 | 260 | 250 | 300 | 0 | 300 | 350 |

**DBE – Design Basis Event (EQ with 2,500 year reoccurrence period).**

**Performance above 3 x DBE implies capital failure will not contribute to combined probability of failure of PF-4.**

# Column Capital Test Program (CCTP)
# Defining the Loading Protocol

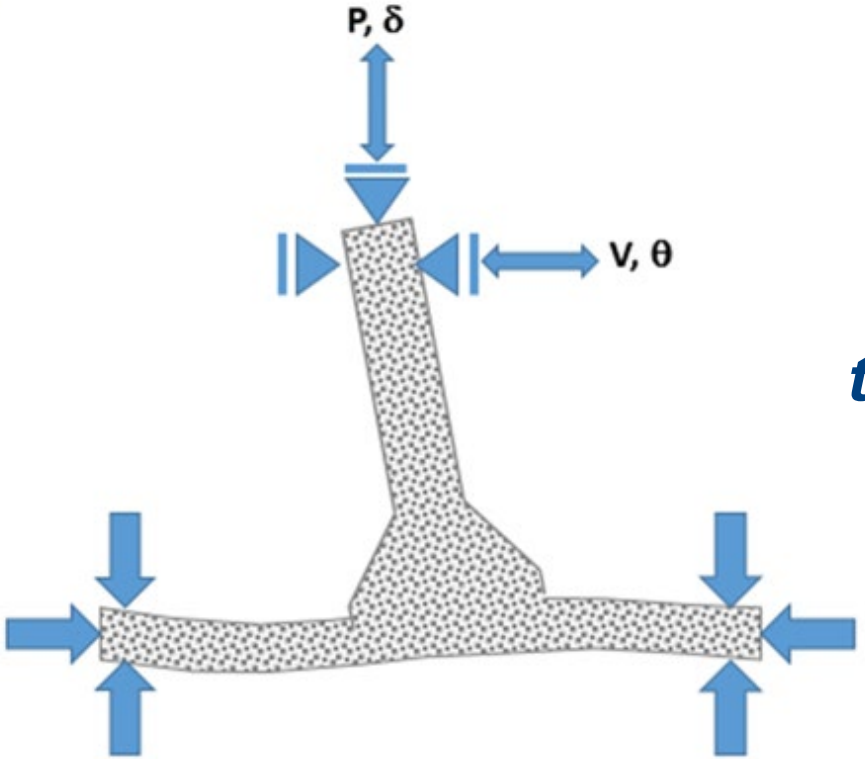



Final Loading Protocol – some science, some judgment

# Column Capital Test Program

## Specimen Development

# Column Capital Test Program (CCTP) Pre-testing Modeling and Evaluation

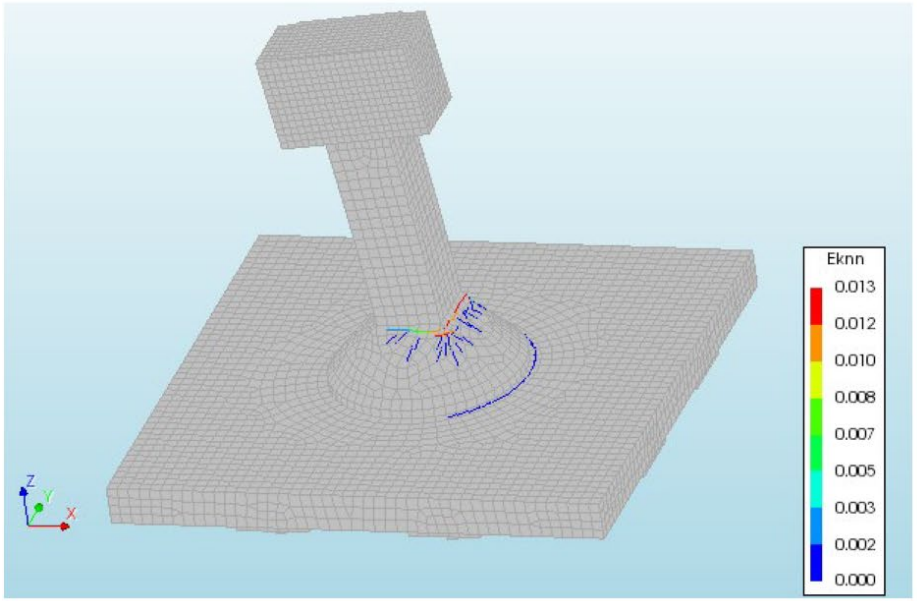



***Testing upside down to facilitate stability of specimen***

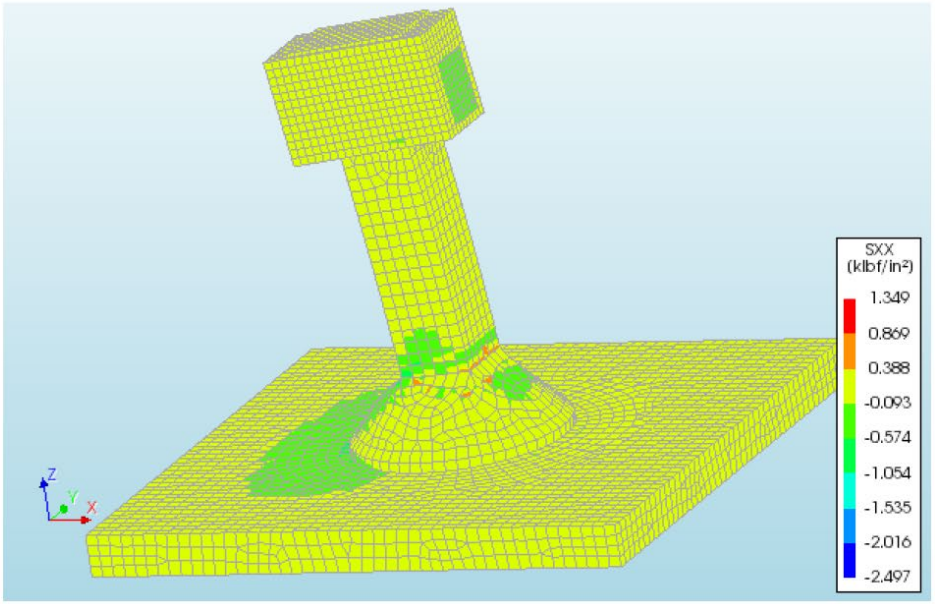
**Schematic of Specimen Test as Defined in Contract Documents**

# Column Capital Test Program (CCTP) Pre-testing Modeling and Evaluation

## Nonlinear Load History (Case 6 and $f_c' = 4$ ksi)




Normal crack strain Eknn




Normal stress $\sigma_x$

**Modeling to Refine Specimen by Dr. Suiwen Wu of UNR Using DIANA**

Image Source – University of Nevada – Reno (UNR)

# Column Capital Test Program (CCTP) Pretesting Modeling and Evaluation

- 13.5'x13.5' plan dimensions for slab
- Center-to-center distance of pin supports is 12'

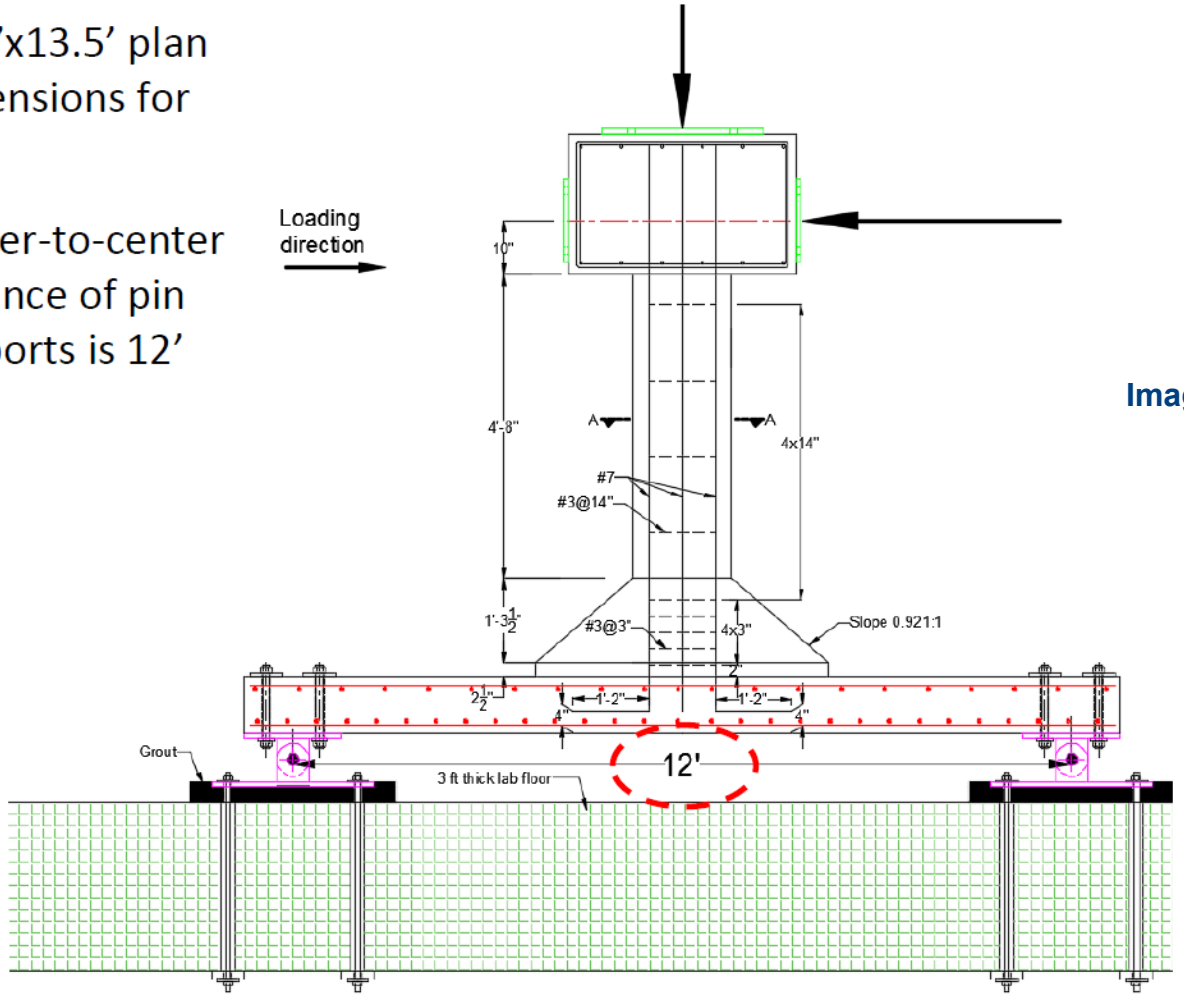
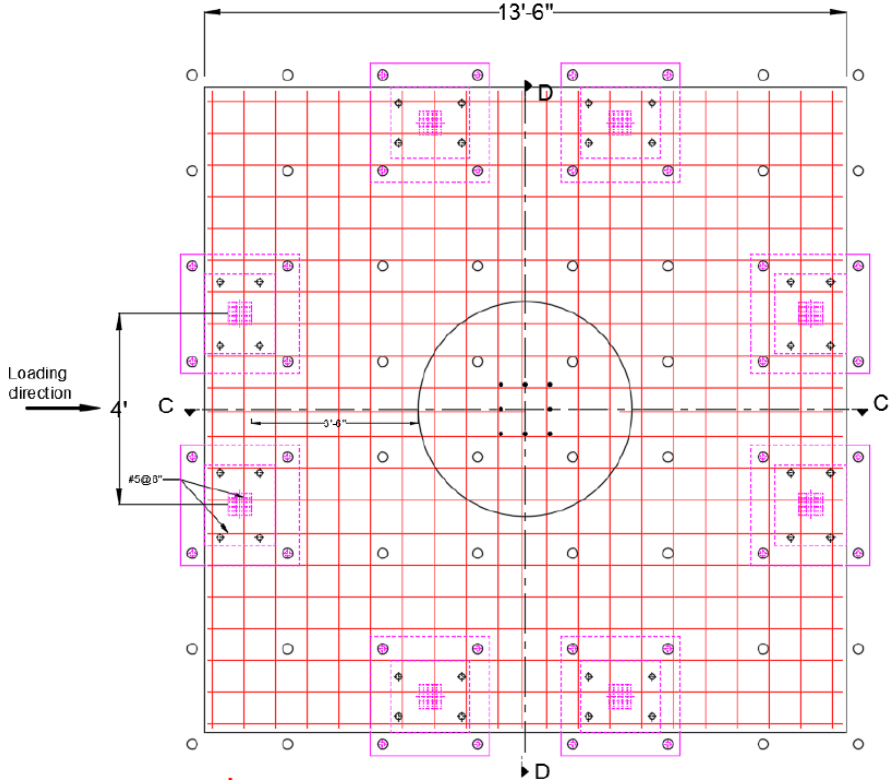
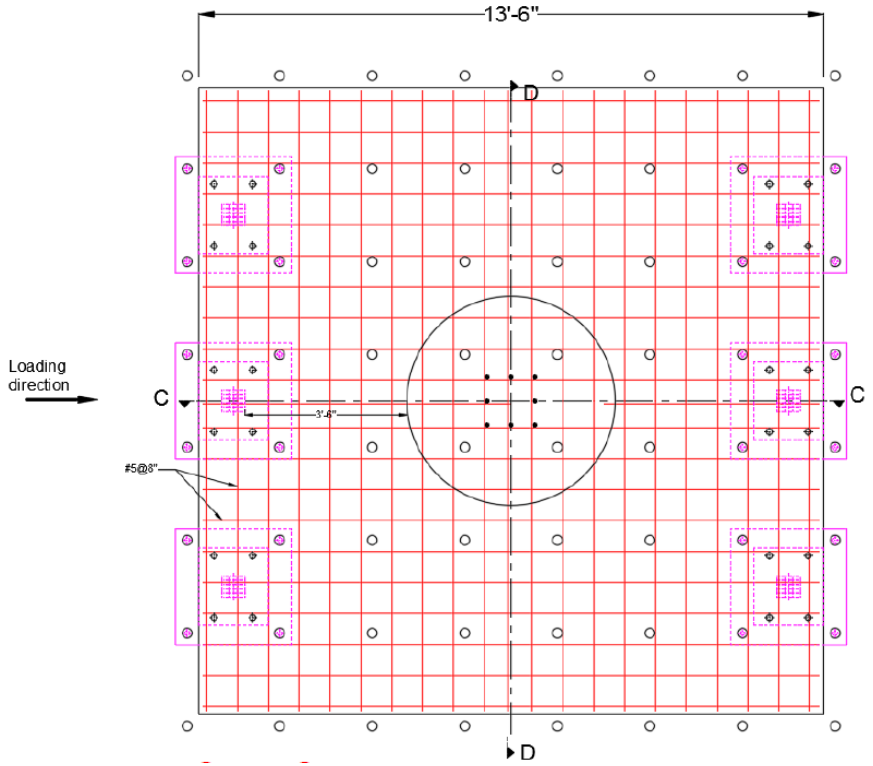



Image Source - UNR

## Development of Specimen

# Column Capital Test Program (CCTP) Pre-testing Modeling and Evaluation

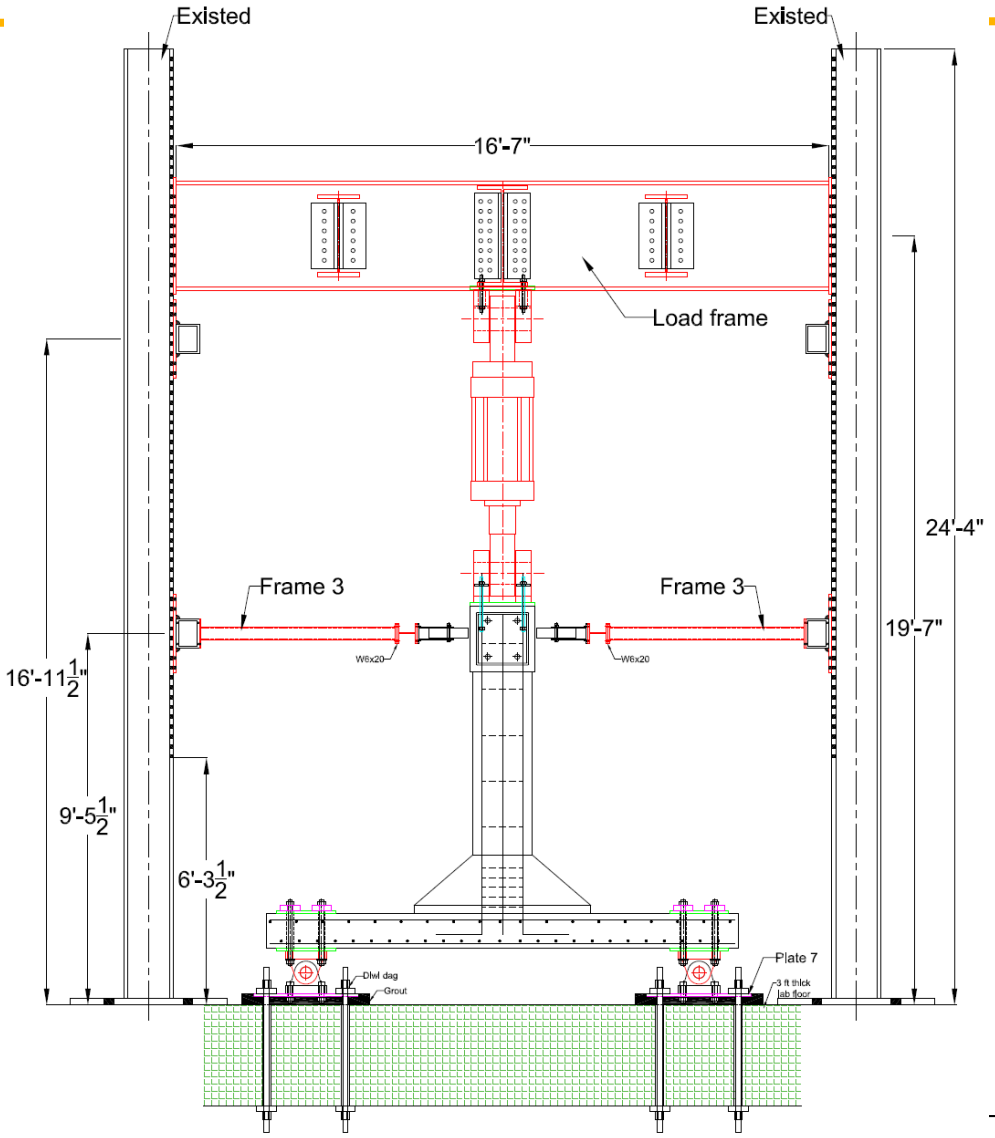



## Development of Specimen – Support Configuration

Image Source - UNR

# Column Capital Test Program (CCTP) Final Specimen Configuration




***Schematic of Load Frame and Specimen***

Image Source - UNR

# Column Capital Test Program

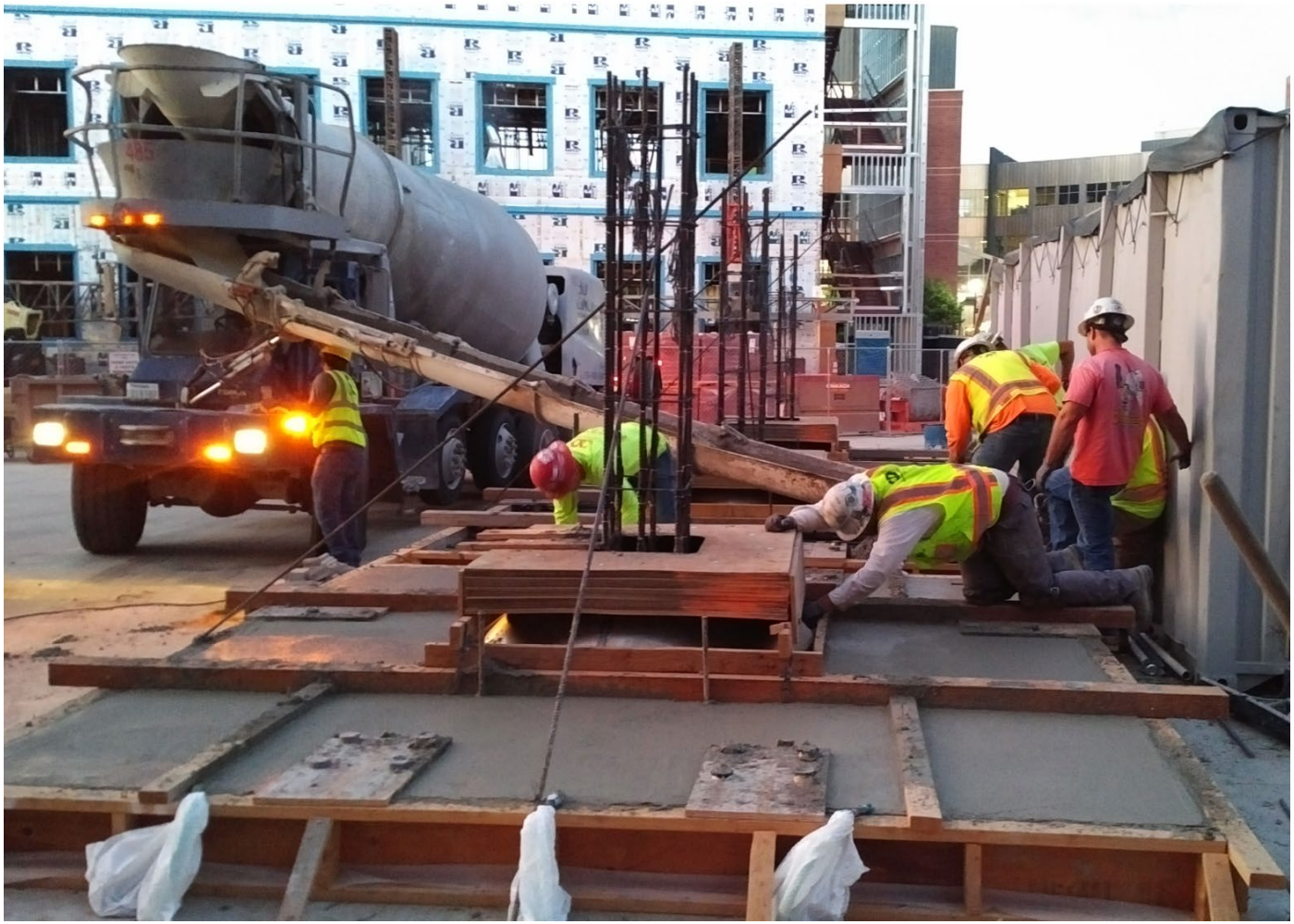
## Specimen Construction

## At University of Nevada - Reno

# Column Capital Test Program (CCTP) Specimen Construction


***Final Rebar Configuration July 23, 2019***

# Column Capital Test Program (CCTP) Specimen Construction



*Concrete Placement July 24, 2019*

# Column Capital Test Program (CCTP) Specimen Construction

***CFRP Installation September 2019***

# Column Capital Test Program (CCTP) Specimen Construction

*Specimens Following Installation of CFRP*

Image Source - UNR

# Column Capital Test Program (CCTP) Specimen Test Model Setup

***Specimen 1 Before Testing***

# Column Capital Test Program

## Specimen Testing

# Column Capital Test Program (CCTP) Specimen Testing

***Specimen 1 at Failure***
***Load Step 8***
***~6% drift***

***P = 0 k***
***M = Mp ~= 400 ft-k***

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# Column Capital Test Program (CCTP) Specimen Testing


***Specimen 2 at Slab Punching Shear Failure Load Step 6***

***P ~= 600 k***

***M = $M_{P\text{-}\Delta}$ ~= 50 ft-k***

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# Column Capital Test Program (CCTP) Specimen Testing

***Specimen 4 at Failure Load Step 9***

***P = ~510 k***

***M = $M_{P-\Delta}$ ~= 50 ft-k***

# Column Capital Test Program (CCTP) Conclusion

- The unreinforced capitals are incredibly robust.
- Behavior was mostly linear over full loading protocol.
- Punching shear strength will not be diminished.
- FEA could not predict capacity. Grossly in error.

# LANL/UNR CCTP and Los Alamos Seismology

## Questions?

## Contact:

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